Multi-Mode Ground Reconfigurable MIMO Antenna System

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Abstract—In this work, a novel 4-element, meandered-line inverted F-shaped antenna is presented. The proposed design is multi-band, frequency agile with multiple-input-multiple-output (MIMO) operation capability. The additional mode of reconfigurability was obtained by controlling the surface currents on the ground plane. Reconfigurability in the proposed design is achieved using a unique combination of PIN and varactor diodes. PIN diodes are used for mode selection while varactor diodes are used for smooth variation of resonant frequencies over tuned bands. The proposed design covers several wireless standards including LTE 900 MHz, GSM 1800, WLAN 2450 MHz with several other bands in the frequency range between 0.7 to 3 GHz. The proposed antenna design is planar and realized on a single printed circuit board. The proposed design is a suitable candidate for mobile terminals and small wireless handheld devices for cognitive radio applications.

Keywords: MIMO, multi-mode, ground plane reconfigurable antenna

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PRESENTATION SCOPE

- Introduction
- Future Trends
- Cognitive Radio
- MIMO Reconfigurable Antennas
- Proposed Antenna Design
- Results Discussion
- Conclusion

INTRODUCTION

- A cognitive radio (CR) is an intelligent radio that can be programmed and configured dynamically.
- CR is an efficient method of spectrum utilization.
- In CR platforms the antenna front end is very important and is usually a Reconfigurable MIMO antenna system (for CR second generation).
- In this work, a 4-element reconfigurable MIMO antennas is presented with additional ground plane reconfigurability for CR applications.
- The proposed design is suitable to be used in wireless handheld devices and mobile terminals.

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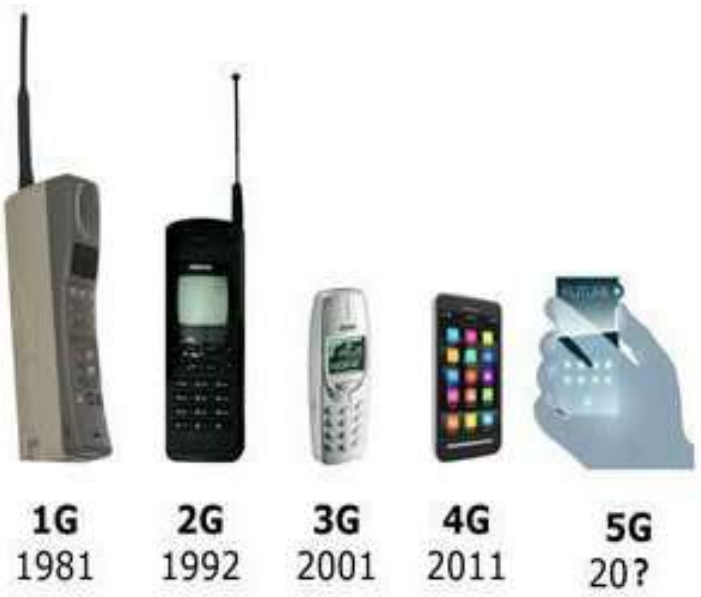
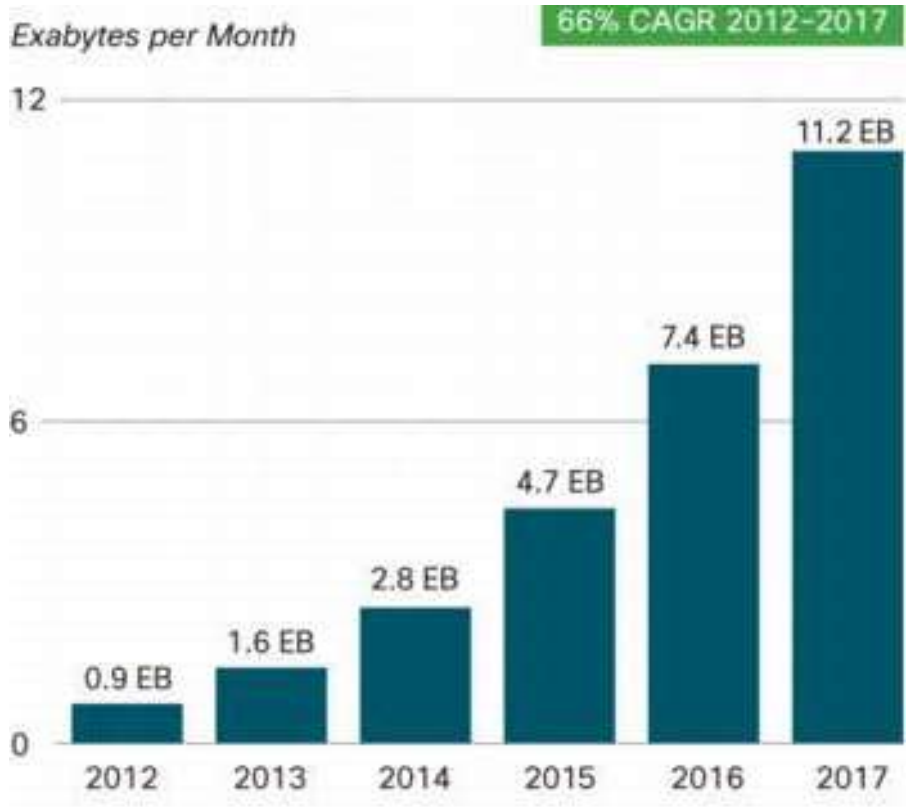
FUTURE TRENDS

- **Future trends of wireless handheld communication devices**
  - **High data rate requirement**
  - **Perform multitude of function**
  - **Operation across several bands is required**
  - **Compact wireless handheld devices with small form factor**
- **To meet these requirements of wireless handheld devices**
  - **MIMO antenna systems**
  - **MIMO reconfigurable antenna systems for Multi-Standard Multi-Band and Cognitive Radios**



DATA RATE REQUIREMENTS

- Tremendous Increase in data rate requirement
- Cisco VNI Mobile Forecast [1]



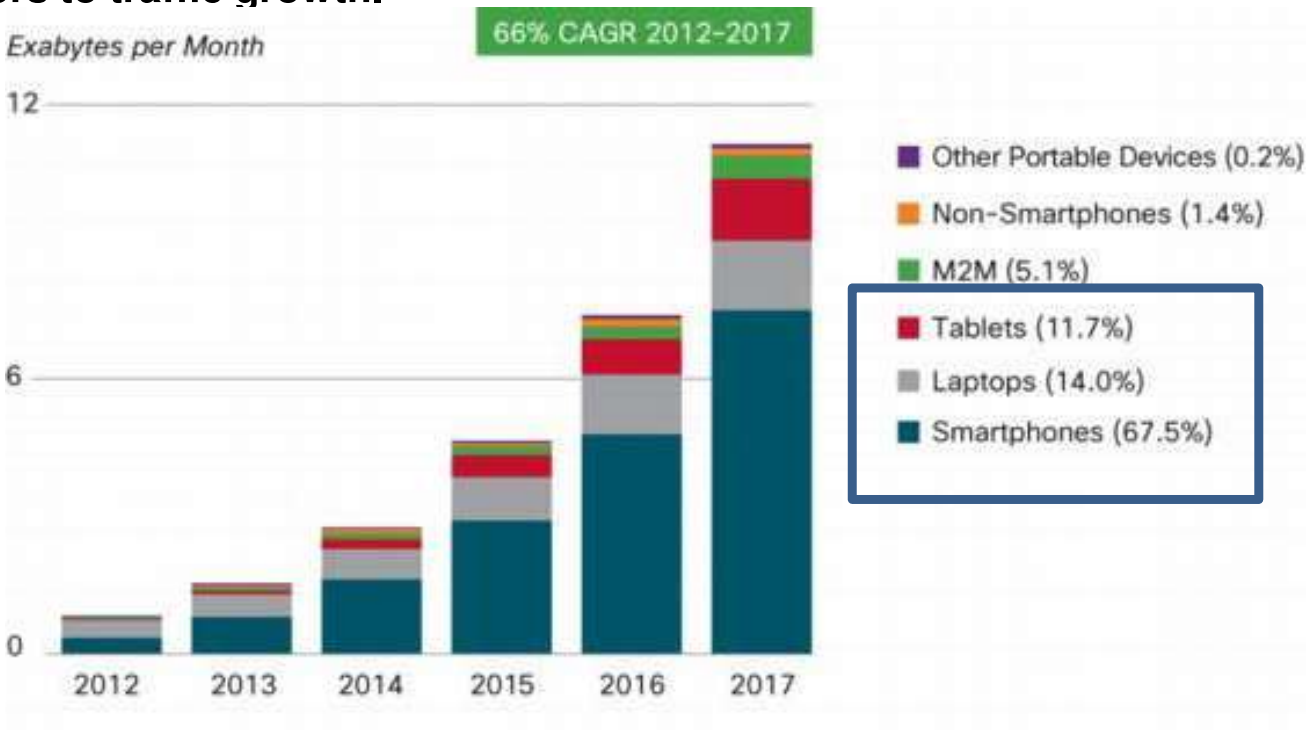
Cisco VNI Forecasts of Mobile Data Traffic by 2017

[1] Source-- Cisco VNI Mobile Forecast, 2013

- CAGR-compound annual growth rate
- Exabytes=10^{18} bytes

FORECAST OF WIRELESS MOBILE DEVICES

- Number of wireless devices accessing mobile networks worldwide is one of the primary contributors to traffic growth.



Global Mobile Data Traffic Forecast by Device Type

[1] Source-- Cisco VNI Mobile Forecast, 2013

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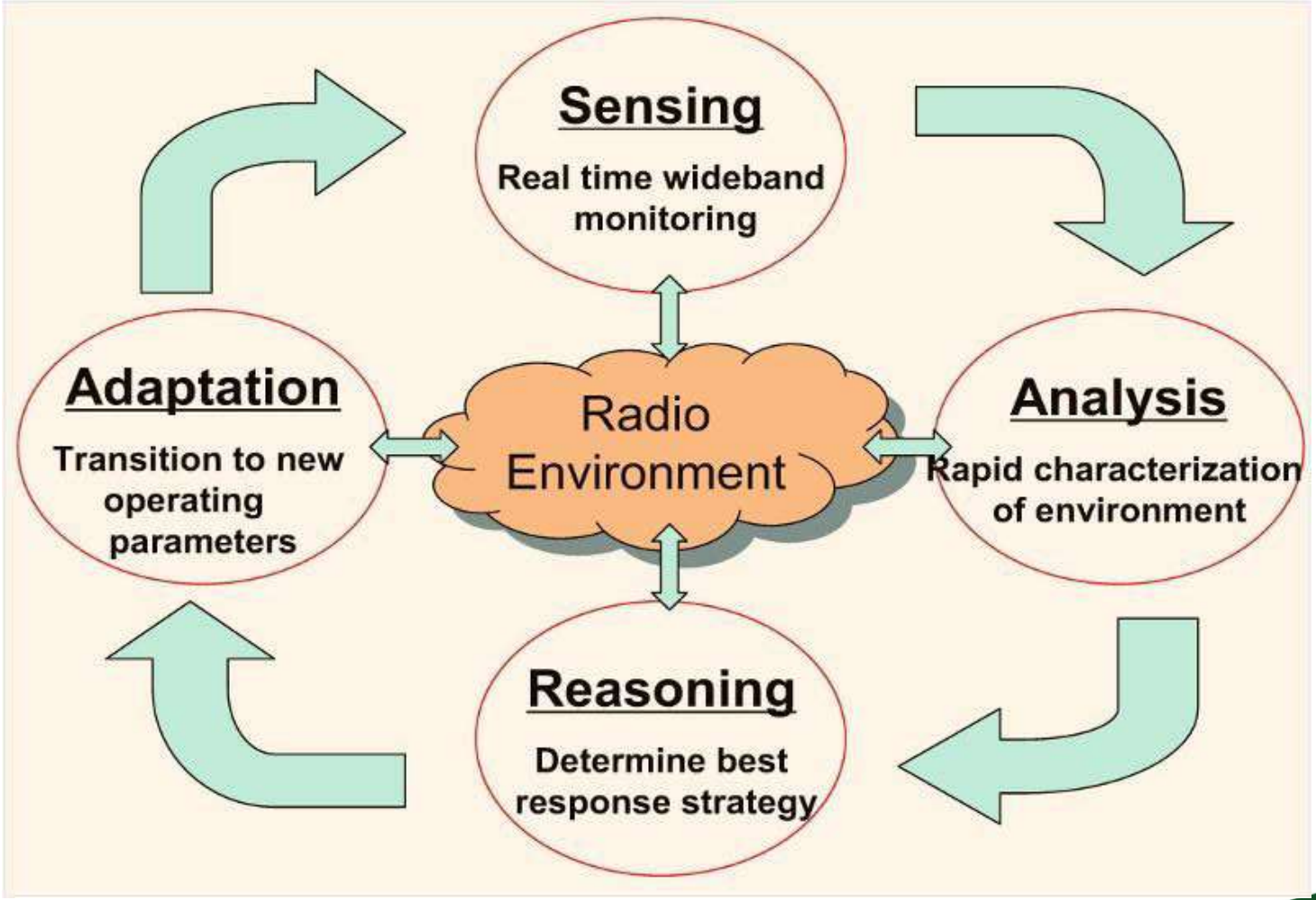
COGNITIVE RADIO (CR)

- **The concept of the revolutionary technique of a cognitive radio (CR) first appeared in literature by J. Mitola in 1999 in his Ph.D dissertation.**
- **According to Federal Communication Commission (FCC).**
  - ***"A radio system employing technology that allows the system to A (software-defined) radio that can change its transmitter parameters based on interaction with the environment in which it operates"***

J. Mitola "Cognitive Radio---An Integrated Agent Architecture for Software Defined Radio." Ph.D, thesis, KTH, (2000).

COGNITIVE RADIO(CR) PLATFORM

An important part of CR front-end are the antennas.



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MIMO RECONFIGURABLE ANTENNAS

- Reconfigurable antenna systems are used to
  - Change an individual radiator's fundamental operating characteristics through electrical, mechanical, or other means.
  - Improve system performance
  - Meet high data rate requirement
- MIMO reconfigurable antenna system are used to
  - Combine both characteristics of MIMO and reconfigurable antennas
  - Efficient spectrum utilization
  - High data rate requirement with better resource utilization

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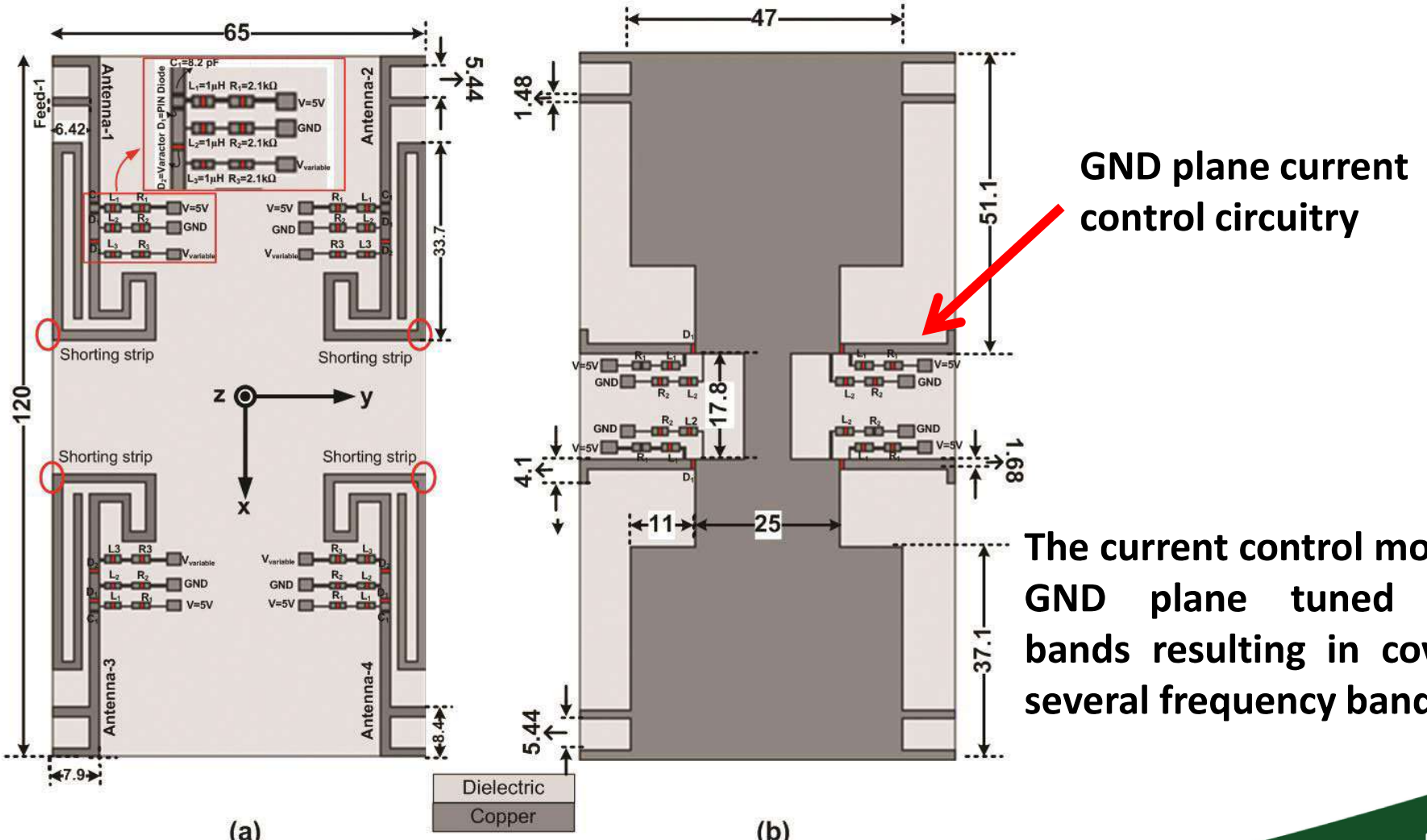
PROPOSED ANTENNA DESIGN

- Four Element Planar Antenna Design

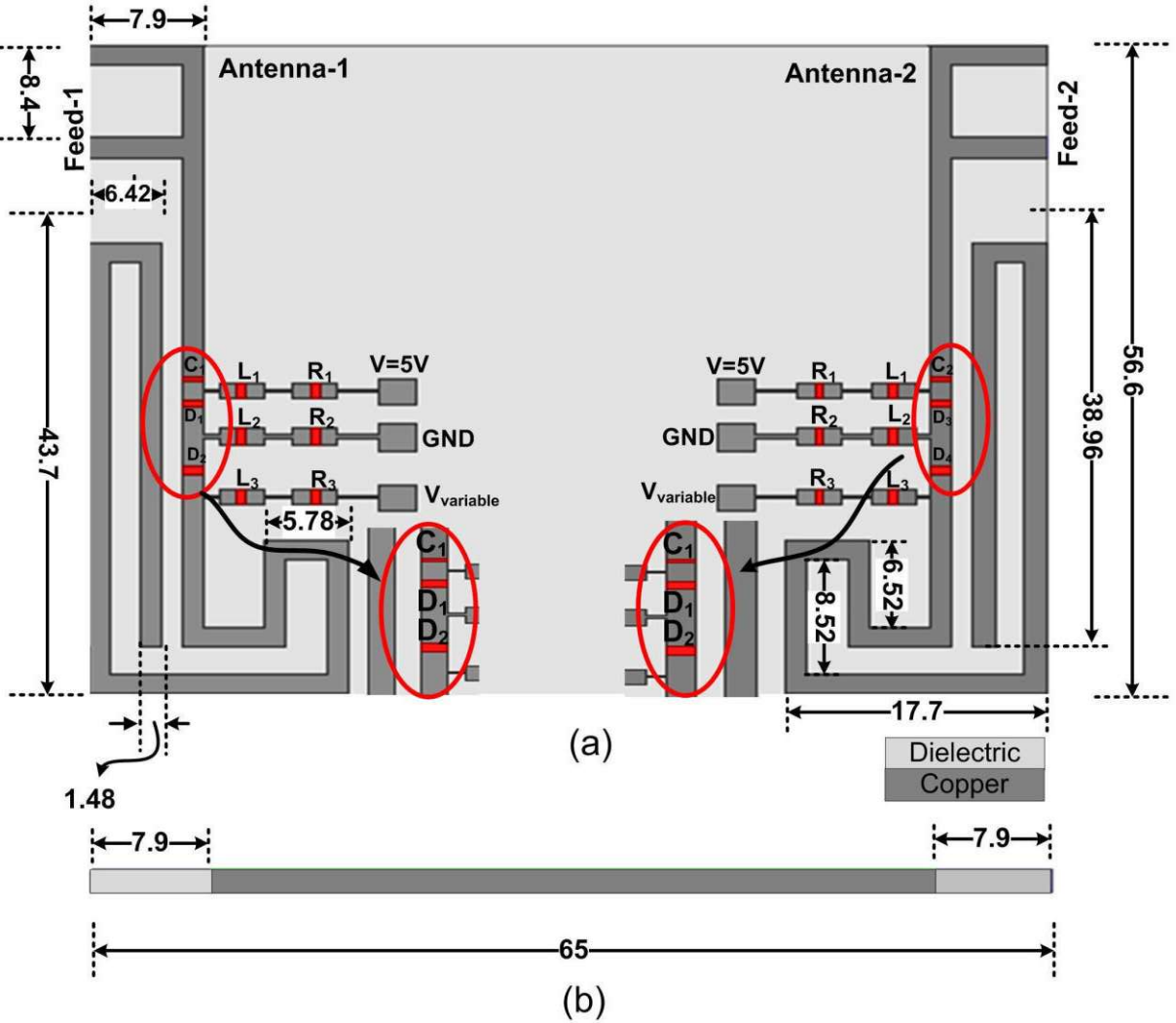


GND plane current control circuitry

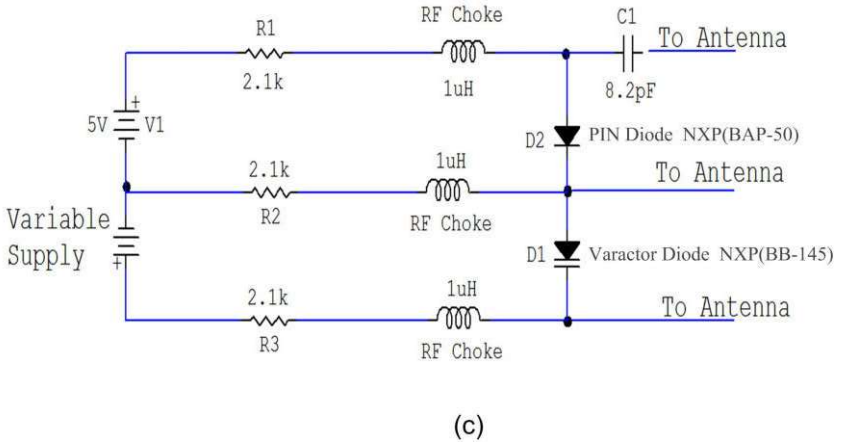
The current control mode on GND plane tuned more bands resulting in covering several frequency bands.

(a) Top View (b) Bottom View

DETAILED SCHEMATIC OF PROPOSED DESIGN

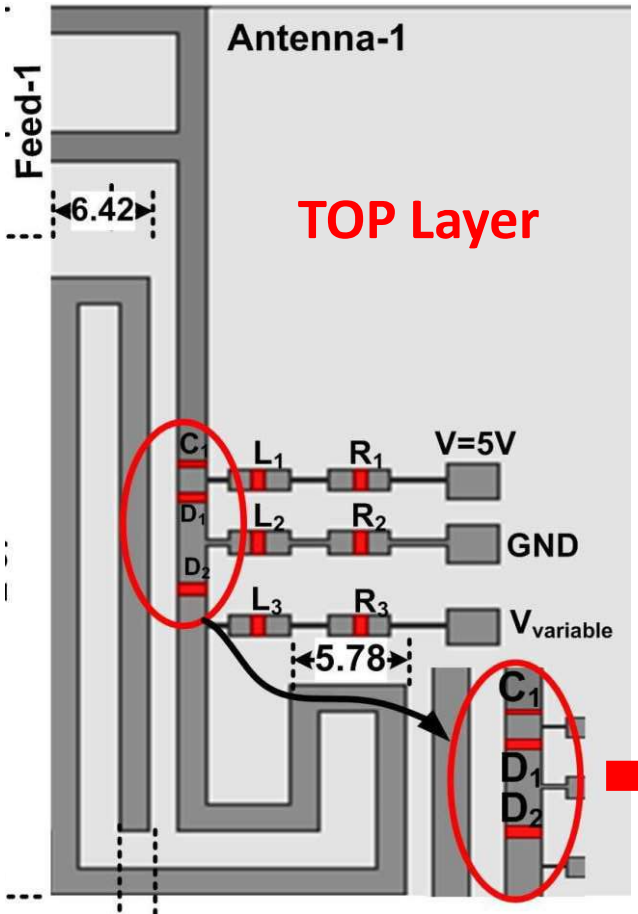


Detailed View of single MIMO Element



(a) Detailed Top View (b) Side View (c) PIN and Varactor diode Biasing Circuit

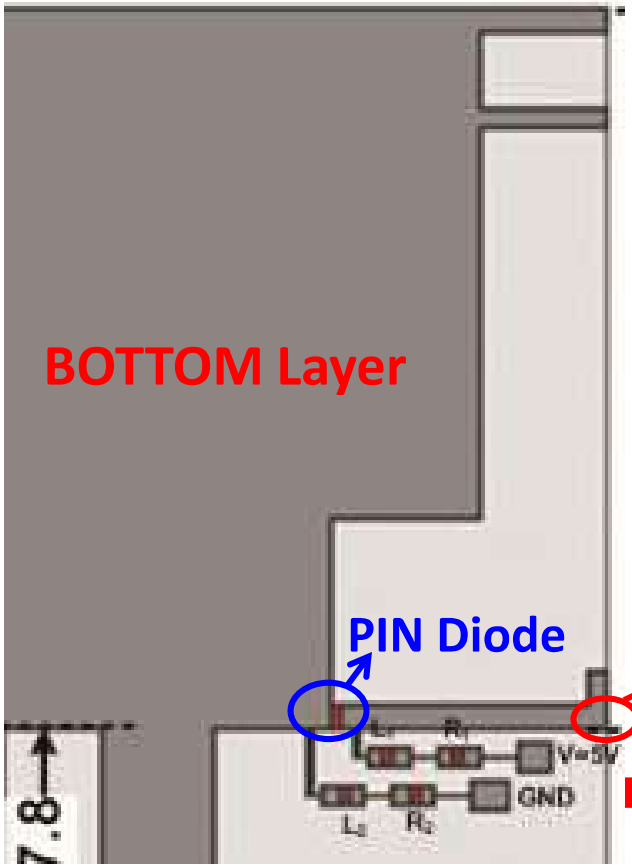
RECONFIGURABLE ANTENNA MODES



- Three modes of operation depending on the PIN diode position
- Varactor diodes are used to vary the tuning range over a wide band

- D_1 is the PIN diodes used for mode selection
- D_2 is the PIN diodes used for mode selection

RECONFIGURABLE ANTENNA MODES



-GND Layer is short circuited using metallic strip with the TOP layer antenna structure.

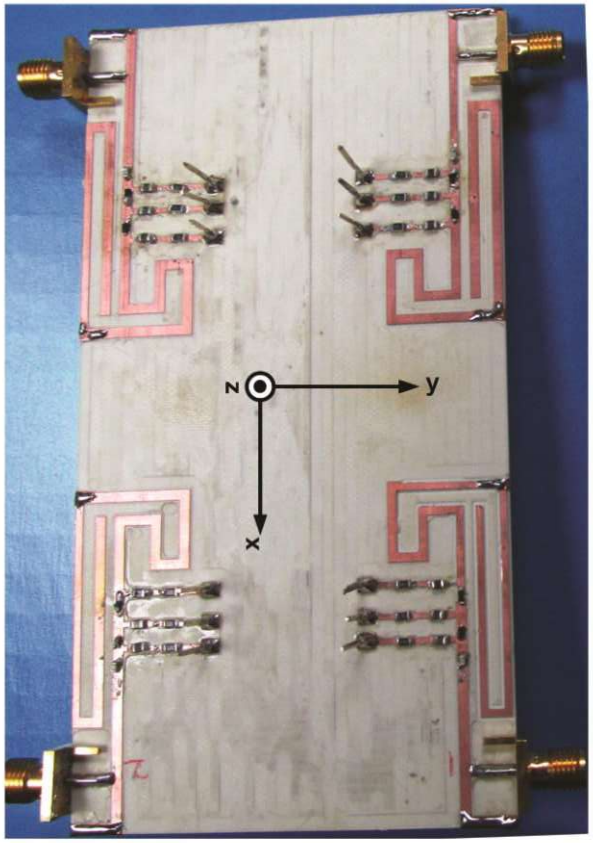
-PIN diode is used to connect/disconnect the two layer metallic structure.

-PIN diode switching is basically used to control the current flow on GND plane resulting in more tuned bands.

-PIN diodes biasing circuit on GND plane

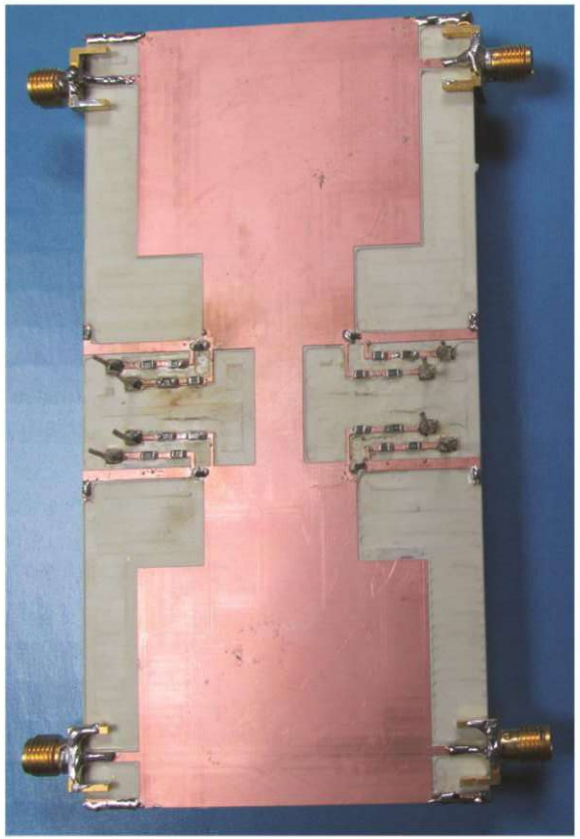
FABRICATED MODEL

Detailed View of fabricated MIMO antenna



(a)

(a) Top View



(b)

(b) Bottom View

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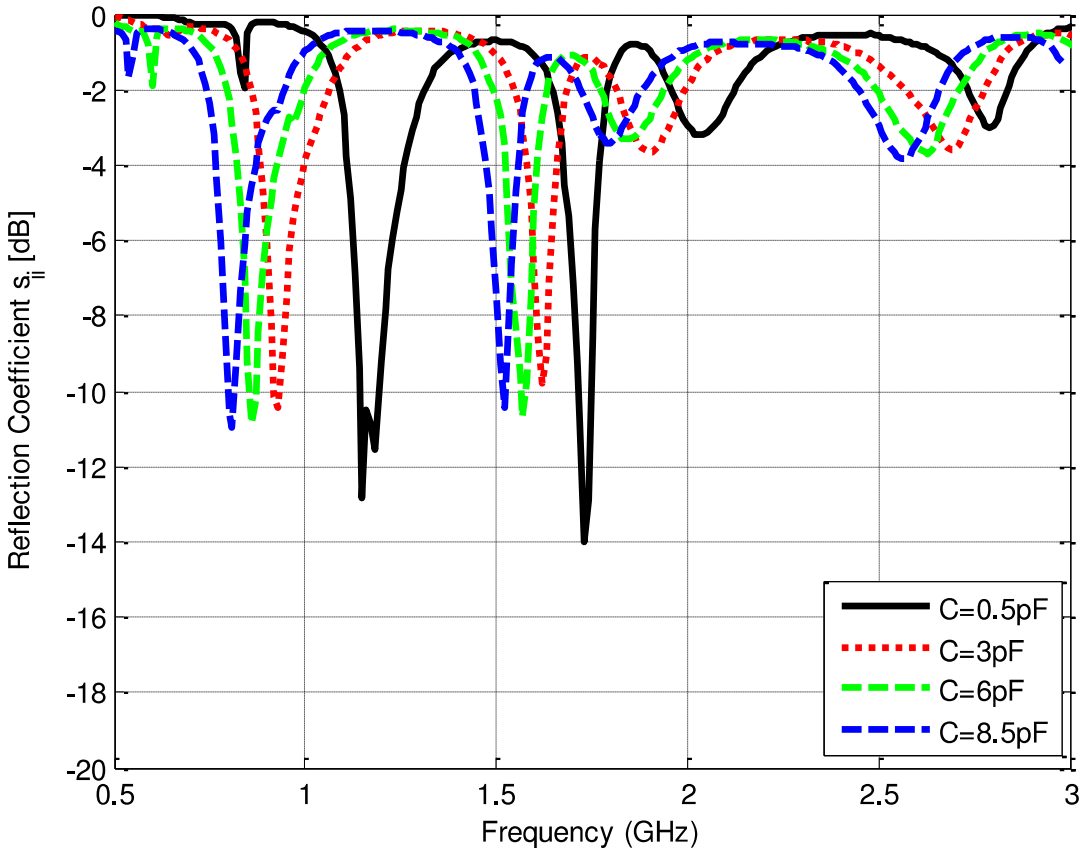
MODE 1: REFLECTION COEFFICIENT

Simulated reflection coefficient s_{ii} of mode-1.

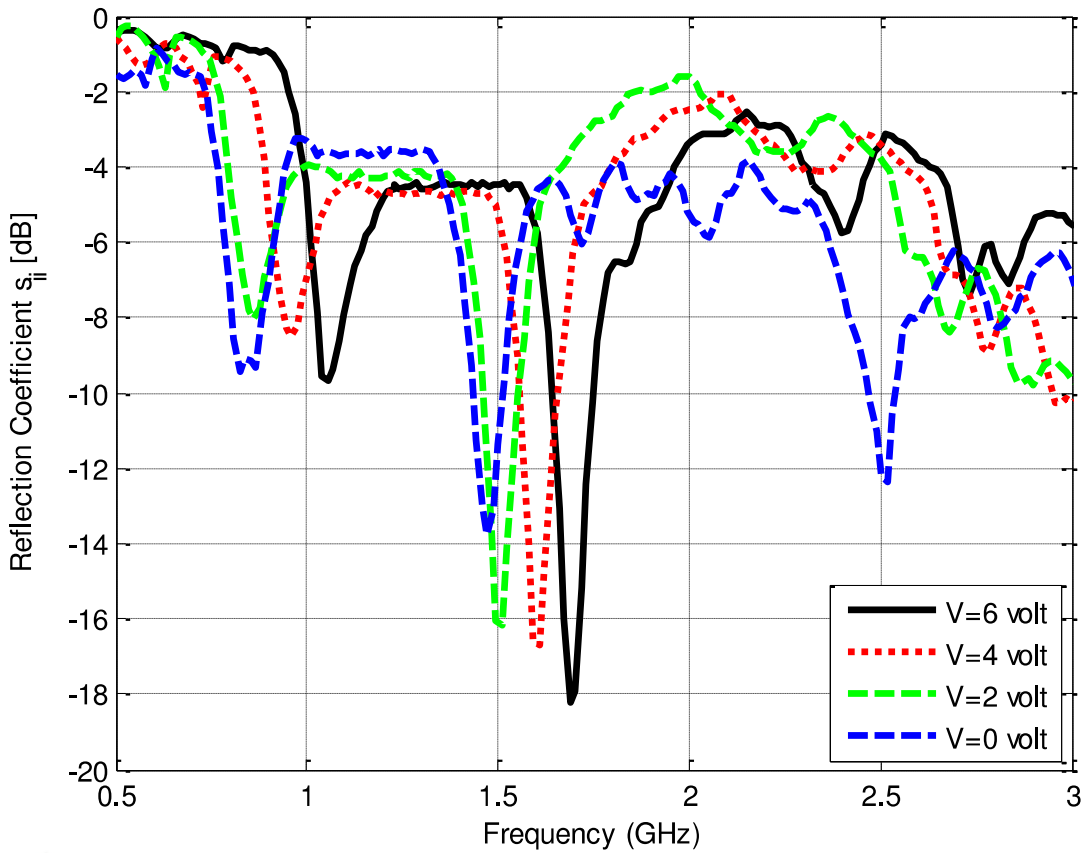


Band-1: 780~1230 MHz BW=60 MHz

Band-2: 1490~1760 MHz BW=50 MHz

MODE 1: REFLECTION COEFFICIENT

Measured reflection coefficient s_{ii} of mode-1.



Band-1: 780~1230 MHz BW=60 MHz

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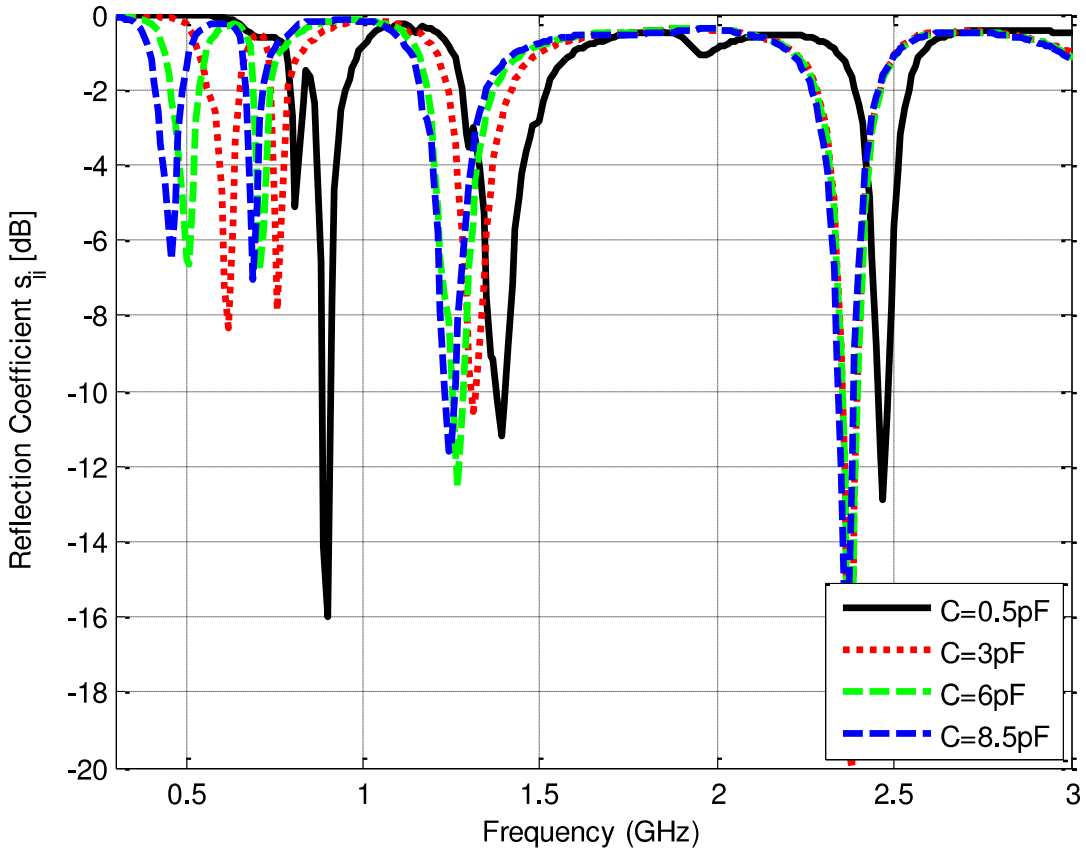
MODE 2: REFLECTION COEFFICIENT

Simulated reflection coefficient s_{ii} of mode-2.



Band-1: 610~920 MHz BW=30 MHz
Band-2: 1210~1430 MHz BW=90 MHz
Band-3: 2.4 MHz BW=100 MHz

MODE 2: REFLECTION COEFFICIENT

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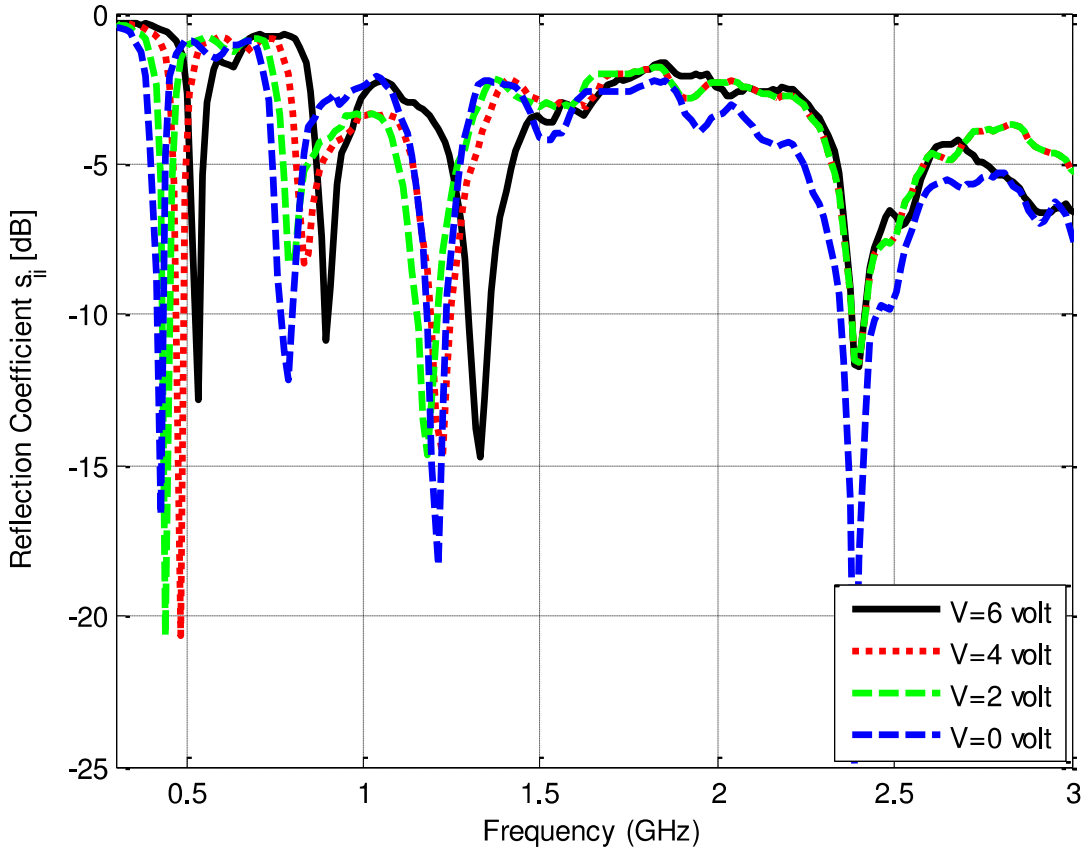

Band-1: 610~920 MHz BW=30 MHz
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Band-3: 2.4 MHz BW=100 MHz

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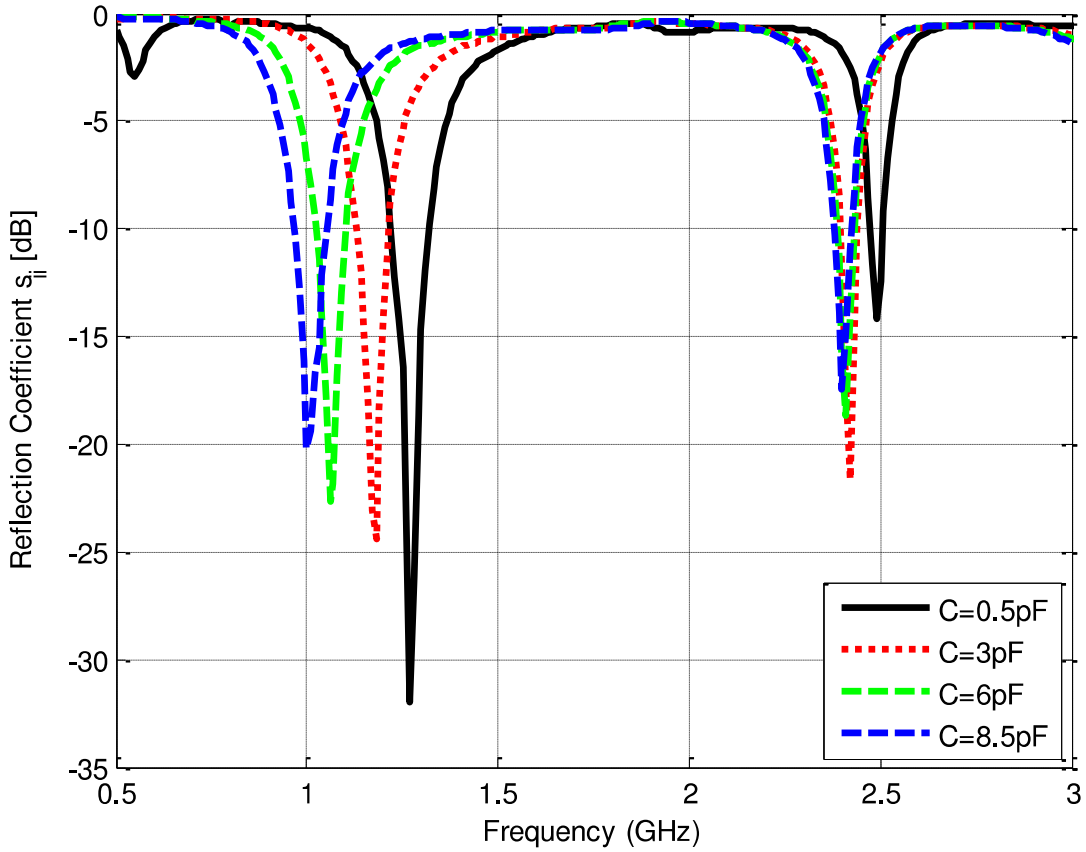
MODE 3: REFLECTION COEFFICIENT

Simulated reflection coefficient s_{ii} of mode-3.

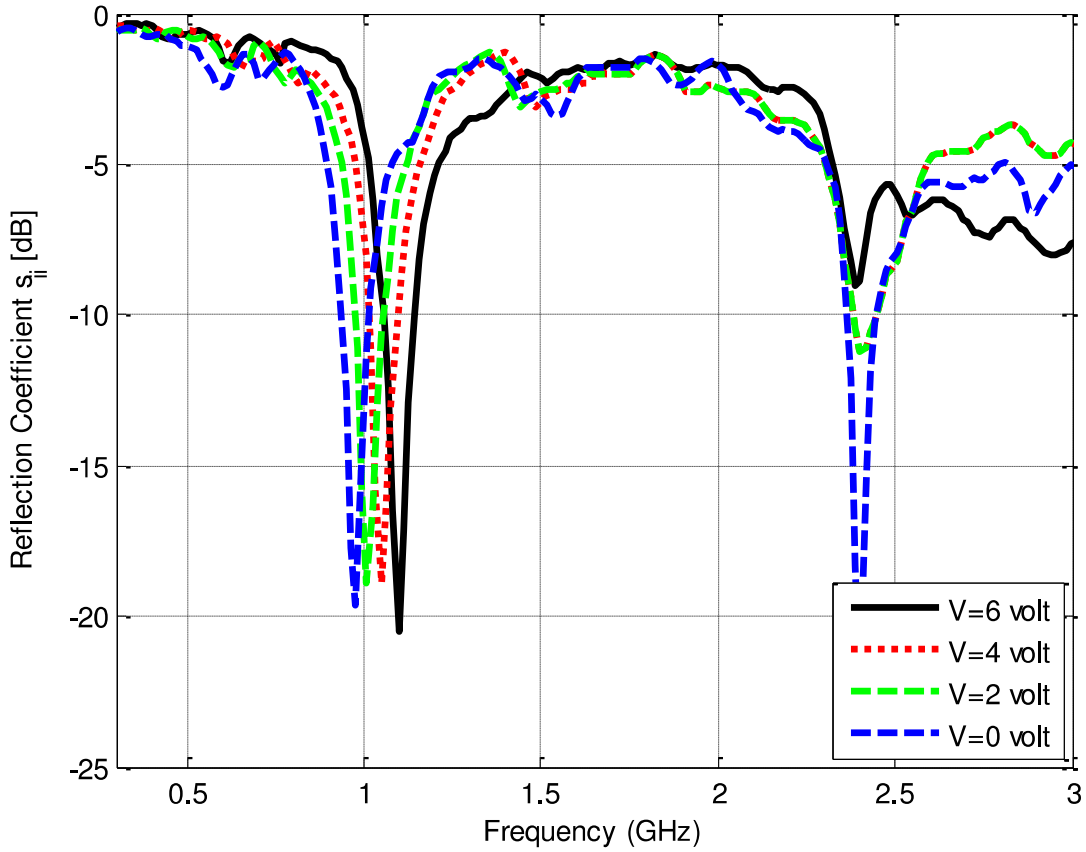


Band-1: 940~1350 MHz BW=140 MHz

Band-2: 2.4 MHz BW=90 MHz

MODE 3: REFLECTION COEFFICIENT

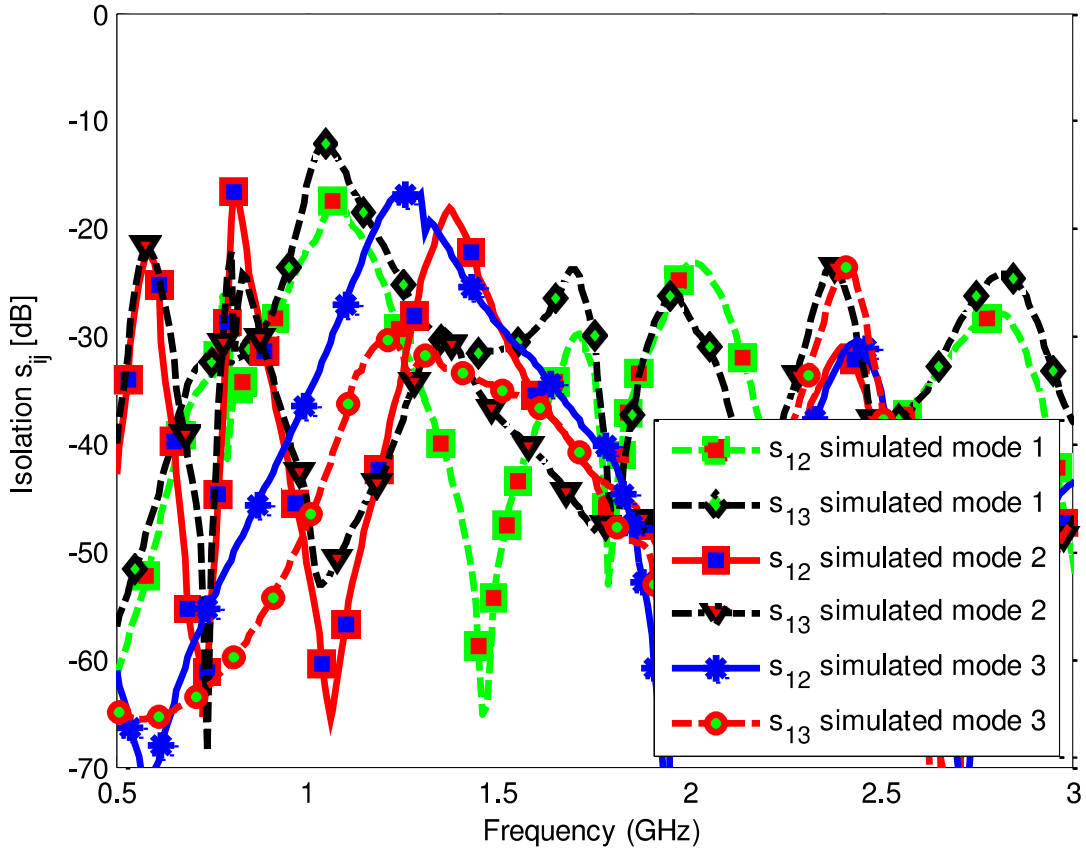
Measured reflection coefficient s_{ii} of mode-3.



Band-1: 940~1350 MHz BW=140 MHz

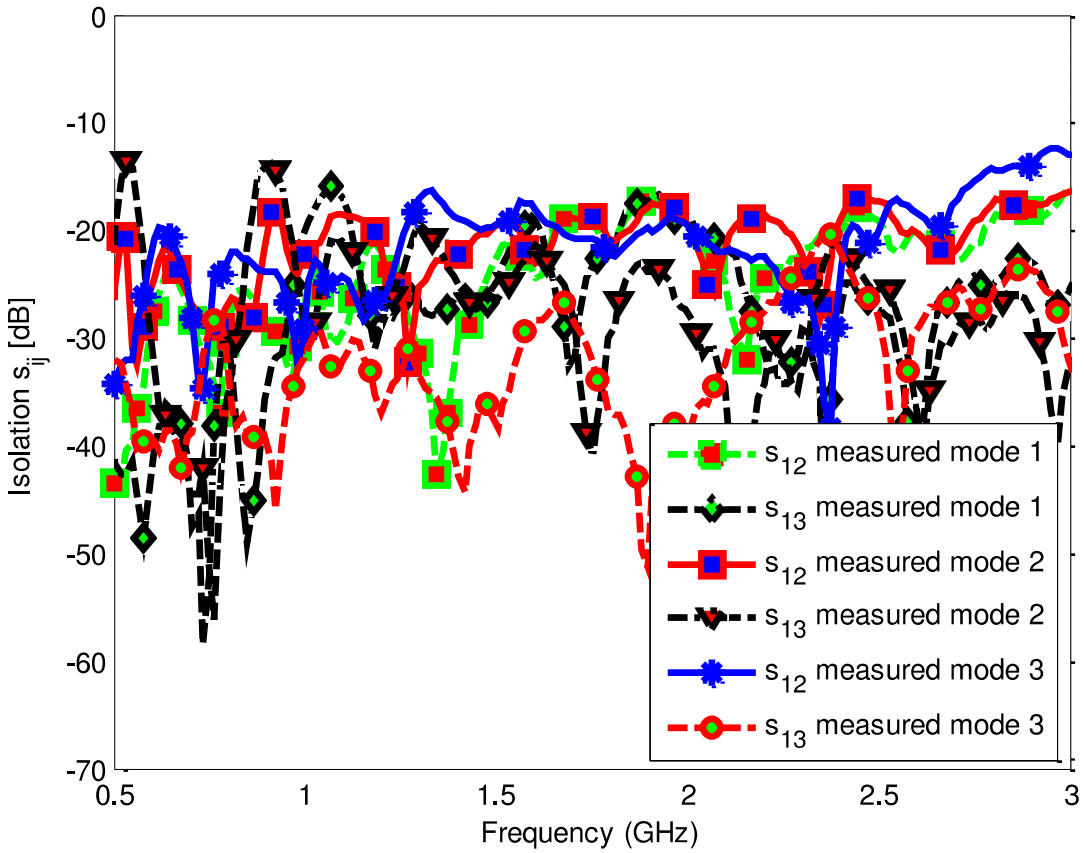
Band-2: 2.4 MHz BW=90 MHz

ISOLATION PLOTS



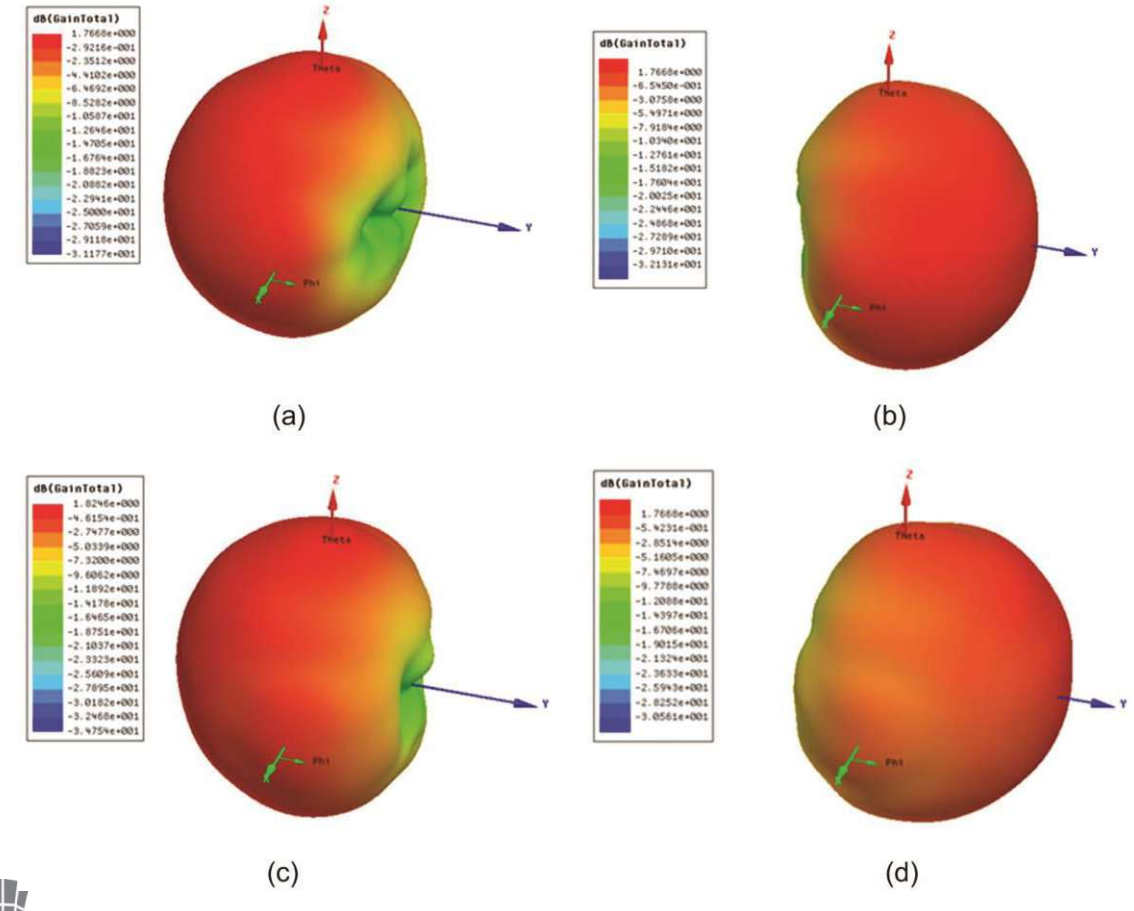
- Simulated isolation curves
- Good isolation is achieved less than -12.17 dB

ISOLATION PLOTS



- Measured isolation curves
- Good isolation is achieved less than -12.46 dB

MODE-1: SIMULATED 3D GAIN PATTERN



Gain Patterns at 1040 MHz
Mode-1: Peak Gain= 1.77dBi

Simulated 3D gain pattern Mode-1 at 1040 MHz (a)Antenna-1 (b) Antenna-2 (c(Antenna-3 (d) Antenna-4

MIMO ANTENNAS PARAMETERS

Peak gain, radiation efficiencies and Envelop Correlation Coefficient

	Band-1		Band-2		Band-3	
	Max Gain(dBi)	Envelop Correlation Coefficient	Max Gain(dBi)	Envelop Correlation Coefficient	Max Gain(dBi)	Envelop Correlation Coefficient
mode 1	1.77	0.15	-2.99	0.089	-	-
mode 2	-6.23	0.117	-2.1	0.0103	-1.43	0.105
Mode 3	-1.125	0.185	-0.8	0.1412	-	-

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CONCLUSIONS

- To meet the high data rate requirement, a compact 4-elements MIMO antenna is presented.
- A reconfigurable single substrate based 4-element planar MIMO antenna system is presented for CR applications.
- The Proposed 4-element reconfigurable MIMO antenna was fabricated on a substrate area of typical smart phone size.
- Planar low profile reconfigurable antennas of comparable sizes covered frequency bands above 2 GHz, thus the proposed one is among the first to coved lower frequency bands.

CONCLUSIONS

- The proposed design added GND plane reconfigurability feature resulting in multi-band/mode operations.
- The proposed design covered well known frequency bands, including LTE, GSM 900, GSM 1800, WLAN 2450 MHz with several other bands as well.
- Good matching between Simulated and measured S parameters is observed, with sufficient BW in almost all covered bands.
- Envelop correlation coefficients are computed for MIMO operation.
- The proposed design is compact, covering lower frequency bands with small form factor suitable for wireless handheld devices.

Acknowledgement

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